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IS THE $a_0(980)$ RESONANCE A $K\overline{K}$ BOUND STATE?

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We have analysed properties of two resonances $a_0(980)$ and $a_0(1450)$ using the $\pi\eta$ and $K\overline{K}$ coupled channel model. Although the forces in the scalar-isovector $K\overline{K}$ channel are attractive the $a_0(980)$ resonance cannot be interpreted as a kaon-antikaon bound state within our model.

Keywords: scalar mesons; coupled channel model; meson-meson interactions.

1. Introduction

Scalars are very controversial mesonic states. Their internal structure is not yet understood. There are different models in which the scalars are treated as simple $q\overline{q}$ mesons, $qq\overline{q}\overline{q}$ states, $K\overline{K}$ bound states or mixed states including glueballs. Two scalar-isovector resonances $a_0(980)$ and $a_0(1450)$ have been observed experimentally. The $a_0(980)$ mass is close to the $K\overline{K}$ threshold so one should check whether the $a_0(980)$ is a $K\overline{K}$ quasi-bound state.

We study the properties of the a_0's within the $\pi\eta$ and $K\overline{K}$ coupled channel model described in Ref. 1. It is based on the separable interactions between mesons:

$$< p|V_{ij}|q >= \lambda_{ij} f_i(p) f_j(q), \qquad i,\, j = 1 \text{ (for } \pi\eta) \text{ or } 2 \text{ (for } K\overline{K}), \tag{1}$$

where p, q are the c. m. momenta, λ_{ij} are the coupling constants, $f_i(p) = 1/(p^2+\beta_i^2)$ are the form factors and β_i are the range parameters. We fix four parameters λ_{11}, λ_{22}, λ_{12} and β_2 by choosing the S-matrix poles related to both $a_0(980)$ and $a_0(1450)$ resonances and the fifth parameter β_1 by comparing the $K\overline{K}/\pi\eta$ branching ratio for the $a_0(980)$ with the experimental value.[2] Below we present some of our results. More of them can be found in Refs. 3, 4.

2. Results

In Fig. 1 the effective mass distributions obtained in the Flatté parametrisation of the Crystal Barrel Collaboration data [2] and in the coupled channel model [3] are compared. The phase space factors are defined as $\rho_i = 2k_i/m_i$ and the production amplitudes are given by

$$F_i = \frac{N g_i}{m_0^2 - m_i^2 - i(\rho_1 g_1^2 + \rho_2 g_2^2)}, \tag{2}$$

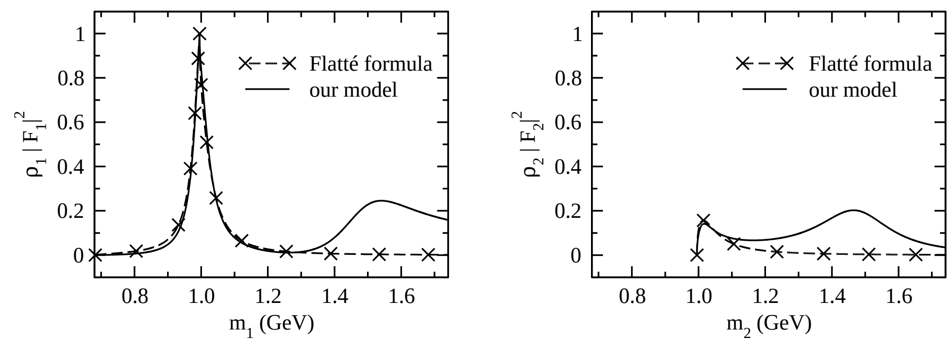

Fig. 1. Effective mass distributions in the $\pi\eta$ and $K\overline{K}$ channels

where m_i are the effective masses, k_i are the channel momenta, g_i are the coupling constants, m_0 is the mass parameter and N is the normalization constant. The production amplitudes are related to the elastic and the transition cross sections by:

$$\rho_1|F_1|^2 = \sigma^{el}_{\pi\eta} k_1 m_1 \tag{3}$$

and

$$\rho_2|F_2|^2 = \sigma_{\pi\eta\rightarrow K\overline{K}}\, k_1 m_1. \tag{4}$$

The Flatté formula describes only a range of the mass distributions near the $a_0(980)$ resonance while our coupled channel model describes both the $a_0(980)$ and the $a_0(1450)$ resonances. For example, we can predict the $K\overline{K}/\pi\eta$ branching ratio in the $a_0(1450)$ mass range. We have calculated it in two mass ranges. For a typical range, between $M_1 = M - \Gamma/2$ and $M_2 = M + \Gamma/2$, where $M = 1474$ MeV and $\Gamma = 265$ MeV one obtains a value of 0.98. The branching ratio is equal to 0.78 if $M_1 = 1300$ MeV and $M_2 = 1471$ MeV. Our predictions are in a good agreement with the experimental value 0.88 ± 0.23 given by the Crystal Barrel Collaboration.[2]

Each resonance decaying in two channels is related to two poles of the S-matrix in the complex momentum planes. The $a_0(980)$ resonance lies close to the $K\overline{K}$ threshold. Both poles corresponding to this state are close to the physical region and influence strongly the $\pi\eta$ and $K\overline{K}$ amplitudes. Having fixed all the model parameters we have obtained an attractive force in the $K\overline{K}$ channel. Now the question is whether a strength of the $K\overline{K}$ force is sufficient to create a kaon-antikaon bound state. A pole position in the $K\overline{K}$ *uncoupled* channel gives us some information about the nature of the $a_0(980)$ state. If a bound state exist then it is connected with a pole on the positive part of the imaginary axis in the complex momentum plane. To arrive to a conclusion we have gradually *reduced* the interchannel coupling from its value down to zero and studied the pole trajectories. In Fig. 2 the trajectories of two $a_0(980)$ poles and two zeros are shown. In the uncoupled case the pole 1 meets the zero related to the pole 2 and is cancelled by it. In the same way the pole 2 is

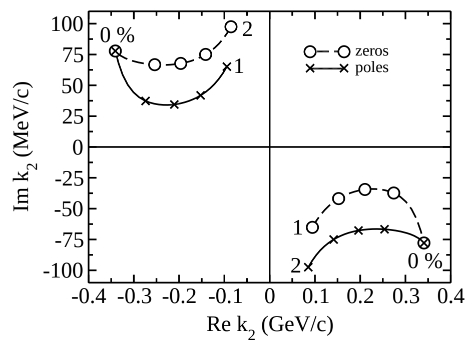

Fig. 2. Trajectories of the S_{22} matrix element poles and zeros related to the $a_0(980)$ resonance in the $K\overline{K}$ complex momentum plane. Crosses and circles indicate a reduction of the interchannel coupling λ_{12}^2 by 25%.

cancelled by the zero related to the pole 1. It means that in this limit both poles disappear from the $K\overline{K}$ channel so the $a_0(980)$ resonance cannot be interpreted as a $K\overline{K}$ bound state.

3. Conclusions

We have constructed the $\pi\eta$ and $K\overline{K}$ coupled channel model. This five-parameter unitary model allows one to describe simultaneously both the $a_0(980)$ and $a_0(1450)$ states. All the parameters have been fitted to experimental values of the masses and widths of both a_0's and to the $K\overline{K}/\pi\eta$ branching ratio measured near the $K\overline{K}$ threshold. The production amplitudes near the $a_0(980)$ resonance and the $K\overline{K}/\pi\eta$ branching ratio for the $a_0(1450)$ resonance, predicted by us, are in good agreement with the Crystal Barrel Collaboration results. Within our model and taking into account the existing experimental data the $a_0(980)$ resonance cannot be interpreted as a $K\overline{K}$ bound state.

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